Adaptive Modem and Method for Adaptive Election of Modulation Mode

The invention is focused on the adaptive modem for data transmission and it is defined in the introduction part of the claim one.

In known data modems fixed frequencies, phases and amplitudes are used. In symbol transmission the information corresponds to waveforms according to the different modulation methods. Each waveform means thus one or several bits (binary digit). Table 1 shows ITU-T standard modems /1/. In the table a symbol equals one, two, etc maximal six bits (64-QAM). In these modems a symbol corresponds one frequency (carrier), one certain phase of the carrier frequency or some amplitude of the carrier frequency on the communication line. Modems are used in all analogy transmission channels for data transmission including radio channels. Restrictions of the technology described above are:

- It uses one carrier frequency, according to the table mostly 1800 Hz.
- Maximal 6 bits correspond to the certain waveform, thus there are a limited number of waveforms to present different symbols, according to the table we have maximal 64 different symbols as a 6 bit presentation with 64-QAM modulation,
- Bandwidth is adjusted to the traditional 300 – 3400 Hz analogy telephone network, according to the table and study the old fashioned FSK technology made slow 1200 bit/s V.23 modem has the narrowest bandwidth 900-2500 Hz.

Nowadays information technology produces only digital two-level data (0 or 1). The need to transmit data has caused the evolution of digital telecommunication networks /2/. The public opinion is thus in digital telecommunication using optical or fibre cables, where this digital on/off transmission is sufficient. Study associated with radio communications and digital telecommunication ISDN phones has developed digital modulation methods /3/, where the digital state (0 or 1) must be transmitted in analogy form.

Common modems have a very limited number of allowed frequencies, phases (for example 8) and amplitude values, Table 1. A disadvantage of present modems is the limited operational range focused to the certain telephone bandwidth or on the other hand range focused the certain radio equipment and channel. They cannot adapt to different type of channels for example the narrower than standard telephone or radio channel or on the other hand the broader bandwidth. Using present modems we cannot have fast data transmission or proper speech or picture transmission.

The limitation of the present ISDN technology is the fixed standard communication and speed of B-channel 64 kbit/s between the subscriber and the exchange /4/. The service offers two B-channels and one C-channel 16 kbit/s.

The adaptive modem can handle much more frequencies, phases and amplitudes than common

modems in generation of different waveforms. The adaptive modem is not limited to a fixed modulation method but it adapts to the possibilities of the transmission channel in use. Characteristic for the invention is what is presented in the claims.

Table 1 ITU standard modems /1/ and /3/

Year	Recommen-dation	Bit rate bit/s	Spectrum Hz Measured	Carrier frequency Hz	Symbol rate baud	Modulation
1964	V.21	300			300	FSK
1964	V.23	1200	900 - 2500	1300, 2100	1200	FSK
1968	V.26	2400	900 - 2700	1800	1200	4-DPSK
1972	V.26 bis	2400	900 - 2700	1800	1200	4-DPSK
1976	V.27 ter	4800	800 - 2900	1800	1600	8-DPSK
1976	V.29	9600		1700	2400	16-QAM
1980	V.22	1200	600 - 2900	1200, 2400	600	4-DPSK
1984	V.22 bis	2400	600 - 2950	1200, 2400	600	16-QAM
1984	V.32	9600	300 - 2950	1800	2400	16-QAM
1984	V.33	14400	300 - 3200	1800	2400	32-QAM
1994	V.34 version 96	28800 31200 33600		1800	2400 2800 3000 3200 3429	16-QAM 32-QAM 64-QAM

The invention includes that waveforms used correspond to the rich symbol file, in theory almost unlimited number of symbols, thus we get the following advantages:

- The transmission speed of the telephone subscriber over the Internet or over the common telecommunication network is higher than the present ISDN 64 kbit/s or the modem 33.6 kbit.
- The data communication is much faster because waveforms in the adaptive modem algorithm correspond to a larger number of bits than presently. Using the equivalent symbol rate we can transmit much more bits than nowadays.
- Based on the adaptive performance the modem suits to most telecommunications systems in use and the bandwidths their communication channels provide (including radio and telecommunication channels), which is a quality the common modems cannot provide.

- The adaptation to the communication channel available is made by software without any change in the mechanic structure or interconnection of the adaptive modem. In the same way the operation mode can be changed on the radio frequencies. By the parameter changes the selections like modulation method, transmission speed and quality of service (bit error rate) are made.
- The adaptive modem fits its performance to each available channel and transmission environment by optimising automatically the functions according to the criterion selected. Criterions may be for example the channel bandwidth and frequencies, the bit error rate allowed during telecommunication, transmission speed needed, encryption algorithm, error correction etc. Modem uses for waveform generation a calculation algorithm and digital to analogy transform and an interface unit between the processor and the telecommunication network. In reception we need similarly an interface unit, an analogy to digital transformer, a calculation algorithm for waveform detection and a processor. Between the computer and the modem we have a standard connection.

In the following the invention is explained more exactly referring to the enclosed figures, where
Figure 1 is a block diagram of the software modem card.
Figure 2 presents the amplitude modulation.
Figure 3 presents the phase modulation.
Figure 4 presents the amplitude and phase modulation.
Figure 5 presents the sum waveform of several different frequencies.
Figure 6 is a block diagram of the modem card of the radio modem.

Figure 1 block diagram left side presents a computer PC, where the software modem interfaces ISA-, PCI- or USB-bus. The modem part on the card gets the power, data- and address signals and the interruption signals through the interface. The modem card has buffer circuits for the signals.

SIGNAL TRANSMISSION

The main component of the modem part is the signal processor, which gets the on process or the transmitting data from the PC data bus. In reception the signal processor feeds data to the PC data bus. The processor also partly takes care of side tones and echo cancelling. The modem software is loaded through the PC data and address bus. Memory is EEPROM type, which can be programmed electrically.

The modulated digital data from signal processor is transformed to analogy by digital to analogy converter. Its analogy voltage message is connected to an opto isolator unit, which separates galvanic the telecommunication network interface from the converter.

The output voltage of the signal is lead to the stepwise controlled amplifier the gain of which is regulated with resistors proper for the telecommunication network. The output voltage of the

amplifier is connected to the resistor bridge from where the signal proceeds through a rectifier to incoming call identification and overvoltage protection circuit. From there the modem signal proceeds into the two-wired telecommunication network.

SIGNAL RECEPTION

The modem signal from the telecommunication network goes through the incoming call identification and the overvoltage protection circuit to the rectifier, from where the signal is connected to the resistor bridge. The function of the bridge is to build so called side noise free connection or let the incoming modem signal from the telecommunication network pass but reject at the same time the outgoing modem signal to the telecommunication network to get connected to the amplifier of the reception.

The incoming modem signal proceeds automatically to the level locking amplifier, which identifies the signal magnitude and after that locks the proper amplification factor. This adaptive action assists the error free function of the reception especially then, when the received signal levels are weak. From the amplifier the signal proceeds through the opto isolator unit to the analogy digital converter. It converts the analog voltage message into digital for the signal processor. The signal processor detects or demodulated from the digital signal a message, which is lead to the PC data bus.

OTHER PARTS

The function of the call identification and overvoltage protection circuit is to identify the call from a B-subscriber and inform the call to the PC through the opto isolator unit. The function of the unit is also connect through the transmitting and the receiving modem signal. The overvoltage protection rejects the flashing or other high voltages to cause damage to the telecommunication network interface unit. If the PC user is an A-subscriber the control signal is connected through the opto isolator to line interface, and then the modem card is galvanic connected to the telecommunication network. After that the signal processor builds a call sequence to the B-subscriber, and then the connection is ready. The blocks of the interface parts of the telecommunication network get the power from the interface unit power, which does not load the telecommunication network and its power feeding blocks.

GENERATION OF TRANSMISSION WAVEFORM

The adaptive modem applies the Discrete Fourier Transform /5/-/6/ both in the generation of the waveform and in its detection algorithm. The generally known Fourier transform is applied in some measuring equipment as a Fast Fourier Transform (FFT), where we cannot exploit all the transmitted samples in data transmission but onlu in powers of two thus: 2, 4, 8, 16, 32, 64, 128,

256, 512, 1024 etc. The invention like adaptive modem applies the Discrete Fourier Transform and can use all sample numbers encountered in practical applications 8, 9, 10, 11, 12,... 16,...32,... 100,... 1024,... etc, thus we can talk about the adaptive function according to the number of the mark (symbol) length. We have to mention that the transmitted symbol contains N samples, and thus we get the time domain length of the symbol and symbol rate. The possible sample rate (Sound blasters max. 45 000, dsp 120 000, USB 12 000 000 samples /s) of the available technology has effect on the symbol rate. The adaptive modem has not been possible before the technology had developed to the present level.

According to the coding method of the analogy signal like speech we get one (adaptive delta modulation), two or more for example 8 (PCM) bits. The adaptive modem combines the bits into symbols, which can have 1, 2, 3 or more bits, a very large number of bits. The adaptive modem can transmit the coded speech regardless of the coding method used.

With the coded text the adaptive modem offers an analogy transmission counterpart for ASCII-code. The equal standard codes get their analogy standard counterparts, which is not realised in modems on the market. Coding can be made instead of bit coding as present with different symbols saved in the computer memory into the analogy transmission mode using the adaptive modem. We will develop new standards for the analogy coding of different digital symbols, text, picture, map etc.

In figure 1 we have a low sine wave 0-bit and a high wave is 1-bit. In figure 1 we present only amplitude modulation. It is usual that fast direct cable connections use digital transmission, where 1-bit is a voltage value over a threshold and 0-bit is the voltage value below that threshold. In figure 1 we present the letter "H" ASCII code with the most trivial amplitude modulation. It has only one wavelength (18 samples), no phase changes and only one bit in every wavelength. In figure the vertical axis present the voltage and the horizontal axis is time. White vertical lines are at every tenth sample.

Figure 2 is the same ASCII code and the letter "H" is presented by the pure phase modulation. If the wave has no phase change in the beginning, it is 0-bit. If the change is 180 degrees, it is interpreted as 1. In figure 2 we have thus H = 01001000.

If we combine the figures 1 and 2 we get the presentation of figure 3 for amplitude and phase modulation. A most simply situation. In figure 3 every wavelength transmits two bits. The first one is amplitude modulated and the second is phase modulated. In figure three we have a message "Hä".

If we are satisfied with the figure 3 presentation, we do not get a very fast line transmission speed. If we use instead of one wave (carrier) four waves (carriers) as follows: the second wavelength is ½ > times the first and the third is ¼ times the first and the fourth is 1/8 times the first and we allow 16 states for amplitude heights and 16 different phase change states, we get the situation in figure 4.

In figure 4 we have quite fast signal, which we can detect with the Discrete Fourier Transform (DFT). We are looking the sum waveform of several different frequencies. The transmitting modem processor has generated the sum waveform using general algorithms.

According to the transmission channel quality we can use for example 20 different frequencies at the same time, 8 bits using one wave (carrier) and modulation method. The number of samples in the basic (first) wavelength (carrier) can be for example 64 and the lowest waveform can be selected according to the limits set by the channel. Still the frequencies can be compressed for example into 50 Hz channels and we can still calculate the detection result with the algorithm derived from the Fourier transform, this means that all the waveforms included in the sum waveform can be detected with the modem processor unit.

DESCRIPTION OF THE ADAPTIVE RADIO MODEM

The block diagram of the software radio modem card is presented in figure 5. The modem card is connected to the PC with ISA, PCI or USB bus according to the version. The modem part in the card gets the power, data and address signals and interruption signals via bus. For the signals we have buffer circuits on the modem card.

The main component on the modem part is the signal processor, which get the transmitting data from the PC data bus. The processor is also available for the use of the spread spectrum technology. The signal processor works using a program memory. The modem software is loaded via the PC data and address bus. The memory is EEPRON type, which can be electrically programmed.

The modulated digital data from signal processor is converted to analogy with a digital to analogy converter. Its analogy voltage message is connected to the step adjustable amplifier, the gain of which can be set with resistors if needed to proper value for the modulator. The output voltage of the amplifier is connected to the modulator, from where the signal proceeds to the RF or radio transmitter. The function of the modulator is to put the transmitting data signal into the high frequency carrier using amplitude or/and phase modulation. The RF transmitter works as the amplifier for the high frequency and modulated carrier, from where the signal is lead to the transmitting antenna (RX-TX-antenna).

The reception of the signal is made by leading the high frequency modem signal from the receiver antenna to the RF-receiver, which works as the amplifier for the high frequency signal. The RF-receiver feeds the demodulator or discriminator, where the data signal is separated from the high frequency carrier. The modem signal proceeds further automatically to the level locking amplifier, which identifies the magnitude of the signal and after that it locks the proper gain factor. This adaptive effect helps the error free function in the reception when the signal levels are weak. The signal proceeds further to the analogy digital converter. It converts the analogy voltage message into

digital for the signal processor. The signal processor in turn detects or demodulates the message from the received digital signal. The message is put to the PC data bus.

The function of the call identification circuit is to identify the incoming radio data message and inform it to the PC. Then PC can be ready for the data signal processed by the signal processor. When PC sends data by radio, a control signal is connected to the transmission interface, and then the RF-transmitter is turned on. After that the signal processor generates the data signal for the transmission.

A modem system according to the presented principle may be both a data modem needed for data transmission and a digital radio where broadband- or so called frequency hopping transmitter is needed and a detector needed in the receiver. The mark, data or symbol waveforms are generally ready saved in the memory and they are detected by calculations with the algorithm based on the Fourier transform. Here we need a signal processor and memory circuits and the software saved in the memory circuit. The essential part of the modem is the interface, by which the program made or in the memory saved waveform according to the transmitted symbol etc is transferred to the telecommunication network or to the radio channel. The applied study of the telecommunication technology, digital signal processing, computer programming and present electronics and signal processors and analogy-to-digital converters in the adaptive modem creates a whole system, which guarantees the transmission speed faster than the present (common) speed. The (data) transmission speed can be adjusted according to the situation. It is rejected only through the bandwidth available, the signal-to-noise present and the level of the information technology and electronics at the moment.

In the patent application presented adaptive modem is much faster than the known standard modems mentioned in the request according to the tests already made. In the known modems the digital data transmission is generated already in the telephone equipment (ISDN phone) or in the first telephone exchange at the other end of the xDSL-subscriber line (no end-to-end principle). The adaptive modem is quite different to that. It is designed to work:

- Over narrow voice transmission lines by end-to-end principle and using complex even arbitrary selectable waveforms according to each need.
- Over existing different analogy channels as modems using analogy transmission lines or even using present analogy channels which are made digitally (ISDN phone) as a faster data transmission alternative for the standard modems. Design principles are exceptional compared to the common data modem design. The function of the adaptive modem is based on the generally known Fourier transform and series theory made by Joseph Fourier (1768-1830). According to the digital signal processing principles the invention uses the Discrete Fourier Transform based calculation algorithm for the calculation of the amplitude and the phase. This makes it necessary to sample the analogy signal in reception and to decode the symbol with the calculation algorithm based on the Discrete Fourier Transform. The known signal processing

and spectrum calculation equipment solutions use the Fast Fourier Transform (FFT) but the adaptive modem uses the Discrete Fourier Transform as a basis for the design of the signal detection and calculation algorithm. This feature is a major part to prove the adaptive modem a real invention and shows its difference to the common designs.

For every carrier used in the multi carrier technology we have calculated in real time their amplitude and phase. So we can detect the transmitted symbol from the so-called signal constellation. The adaptive modem can easily detect more complex signal constellations than the present, in-use, standard or otherwise common modems. We can mention one example of these kind of waveforms n times 1024-QAM. Here n means the number of carriers. The waveform can be adapted to the possibilities offered by the channel, it is - the allowed signal power dynamic range, amplitude max and min limits in volts – the frequency max – min values in Herz – the smallest frequency selectivity in Herz – the smallest amplitude step and – the smallest phase difference.

The achieved data rate can be selected partly according to the above but also by selecting the sample rate and the sample number in the symbol and the resulting symbol rate Bd. These are also some factors which greatly proves the adaptive modem is a real invention and different from the common generally known.

Based on this we have designed a computer assembly language calculation algorithm, which can detect carriers, their amplitudes and phases or detect complex waveforms. Modems having the same functionality is neither presented in publicity nor standardised or known to exist. Thus the adaptive modem is suitable to use over the narrow bandwidth better than any known modem. Examples of these channels are all international over telecommunication network working connected telephone lines, radio telephone connections (NMT, GSM, satellite phone and new voice radio communication systems), military radio communication over different frequency bands (HF, VHF, UHF, etc). The adaptive modem works not only over the narrow band but also as a broad band modem. This is also a factor which greatly proves the adaptive modem is a real invention and different from the common generally known.

Because the computer is interfaced with the radio and the telecommunication network, thus we have designed interfaces for the modem. The interface is a part of the waveform receiver and it includes the signal manipulating circuits needed. The complex waveforms need a very exact level control and synchronism. With the transmission and reception algorithms the system is a complete "adaptive modem" as described in the claim document. This is also a factor which greatly proves the adaptive modem is a real invention and different from the common generally known.

Because the adaptive modem is a method, which uses complex waveforms and each waveform uses several bits in a symbol and the number of bits is much greater than any known narrow voice

band data modem can do, the adaptive modem has a better data transmission rate than common modems.

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